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When's a Gale a Gale? Understanding Wind as an Energetic Force in Mid-Twentieth Century Britain

Abstract

After the Second World War, the British state became interested in the potential of wind as an energy source. Over a period of twenty years, from the mid-1930s to the mid-1950s, scientific and non-scientific communities surveyed airspaces and landscapes to produce the first national wind survey of Britain. This work informed the development and siting of the first wind turbine connected to public electricity supply, in Orkney, Scotland, in 1951. Meteorologists, physicists, and engineers developed ways of "reading" the wind that used highly localized geographies and topographies, and the skills of local people, to accrue data and map the wind regime. Though conducted at a national scale, the research emphasized that the nature of wind—how it behaved, how it was experienced, and how it could be harnessed—was best understood at a local scale. While science

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focused on wind's productive potential, Orkney islanders remained attentive to wind's destructive powers and used turbine-generated wind data to support place-based identities forged, in part, through weather experience.

In a 1943 debate in the UK Parliament's House of Commons, the member for Argyll, Duncan McCallum, spoke about the possibility of using wind power to generate electricity for the highlands and islands of Scotland. There, "Atlantic gales [are] more frequent than breezes," and harnessing the wind could "generate sufficient electrical power in those islands ... to furnish [them] with electricity."[1] McCallum highlighted the rising interest by state and industry in wind as a potential energy source. Wind had been studied as a weather phenomenon through the eighteenth and nineteenth centuries to gain strategic military, economic, and colonial advantages.[2] But the use of wind for energy production in the twentieth century required an enhanced understanding of wind's behavior and power beyond its role in weather formation.

Over a period of twenty years, from the mid-1930s to the mid-1950s, scientific and non-scientific communities in Britain attempted to make sense of wind within a framework of energy production. Knowledge of wind strength and direction remained important, as they had for centuries of sail.[3] But added to these considerations, and crucial for calculations of energy transfer, grid load, and public supply, were questions of consistency and behavior. How much energy could the wind produce, and would it be enough to justify state investment? What technology was required to withstand wind and make it productive? This article argues that to better understand and measure wind, scientists in the 1930s and 1940s approached it through its co-constitutive relationship with land and sea. Scientists and engineers developed ways of using landscape to identify potential wind power sites through studying the effect of topography, architecture, and foliage on the movement of the wind. This work produced the first national wind survey of Britain, which identified the Orkney Islands as Britain's windiest place. Consequently, in 1951, the nation made Orkney the test site of the first turbine connected to the country's public supply grid.[4] Wind data was absorbed into public discourses in Orkney about weather and island life. Following a major storm in 1952, data generated by the turbine helped answer a long-standing question: "when's a gale a gale?" But where scientists focused on wind's productive potential and sought regularity, local understandings of wind power emphasized its unpredictability and capacity for destructiveness, qualities that tested an emergent wind industry.[5]

This article works at the intersections of several historiographies. As Jared Miller and Paul Warde have recently noted, environmental and energy history are "increasingly intertwined."[6] Envirotechnical approaches have eroded the perception of energy as a "vexingly abstract concept" by locating it in human, animal, technological, and environmental processes, thereby drawing attention to its material manifestations.[7] A focus on materiality, as Christopher Jones has shown, "illuminates both the political stakes of energy infrastructure and helps explain the dynamics of energy transitions."[8] Wind, however, does not have the material density of water, oil, or coal. It is a relatively clean form of energy and leaves a smaller mark on the landscape. Perhaps for these reasons, it has not generated comparable quantities of power, policy-making, or conflict, to date, as these other sources of energy. In turn, it has not been subject to extensive historical analysis. But it is not immaterial in either sense of the word. This article focuses on a period in which wind was refigured as an input to a system of energy production, a crucial step in the development of wind turbines that are today helping power transitions away from fossil fuels. Thinking about wind in this way follows Thomas Hughes's suggestion that a sector of the environment can be incorporated into a technological system by bringing it under system control.[9] Hughes does not deny the complexities involved. But this history takes a slightly different line: British engineers and scientists did not bring wind under control so much as they learned about, and learned to work with, wind's variable characteristics. The measuring, mapping, turbine testing, and storm analysis involved in attempts to build a wind-powered system of energy production generated new understandings of how wind behaved in relation to place.

To the extent that they have considered wind power, historians have paid considerably more attention to the technologies developed to render wind useful as an energy source than they have to the myriad cultural and social dimensions of wind's development to that end.[10] Energy historians could gain much by following the example of historians of climatology and meteorology, who have been alert to the ways in which folk knowledge of wind and weather contributed to the formation of more formal scientific structures and understandings.[11] Weather, as Lucy Veale, Georgina Endfield, and Simon Naylor have argued, "shapes the material features of a place and modifies the nature of the human engagement with that place," giving wind an agential role in notions of identity and place that a focus on technology alone fails to capture.[12] Even as scientists sought to develop it as a potential energy source, wind remained a charismatic feature of weather and was inscribed into the ways in which communities understood and responded to weather events and environmental change. Bridging these distinct understandings, this article argues that the processes of knowledge acquisition that enabled wind's development as an energy source relied on fieldwork and local involvement and contributed to place-based identities and discourses. State experiments used meteorological data to establish wind's viability as an energy source but required additional data to understand and establish consistency in where and how wind blows. This information, like the turbines that followed, was situated and understood in relation to place and community.

The state-funded research into wind that took place in the 1940s pushes back the time line of political engagement with modern wind power, more commonly attributed to the global oil crises of the mid-1970s.[13] From the 1930s to the 1950s, wind moved from what Geoffrey Jones has called "the preserve of the curious inventor" to the attention of national governments and industries in the mid-twentieth century, a crucial step for its development as an energy source at scale.[14] Technological progress hinged on the accurate measurement and mapping of wind, an undertaking that rested on broader environmental knowledge. In Orkney in the 1950s, islanders incorporated the scientific data generated by the surveys and turbine tests into existing narratives of identity, resilience, and place, underlining that attempts to categorize the natural world are not only a means to use it but also a profound source for understanding our place within it.

THE ELUSIVENESS OF WIND

On January 15, 1936, Ernest Gold delivered his presidential address to the Royal Meteorological Society (RMS) in London.[15] His subject was "Wind in Britain," and he used the lecture to survey recent developments in methods of measuring the wind using instruments called anemometers, many of which had been made by society members.[16] Gold intended to show how far knowledge of the wind had advanced thanks to the contributions of the RMS. However, by setting out the extent of meteorological knowledge of the wind, he also identified its limits. Running through the address are acknowledgments that the wind, for all the advances in measurement, remained an enigma. Its unpredictability tested the reaches of scientific study and forced meteorologists to bring local knowledge and direct observation into conversation with recordable data and also to admit that some key characteristics of wind behavior were beyond the capabilities of routine data capture.[17] The British Electrical and Allied Industries Research Association (ERA) relied upon the RMS's data to determine where to test prototype wind turbines for the generation of electricity in 1948. But evident too would be the knowledge gaps and need for further work in the form of wind surveys. The processes and pitfalls of measuring the wind in the early twentieth century made wind a quantifiable natural resource, but never a controllable one.

In the eighteenth and nineteenth centuries, the British meteorological study of wind had focused on storms at sea and their detrimental effects on trade, colonial expansion, and military activity. Understandings of global storm patterns and (Admiralty Hydrographer) Francis Beaufort's well-known wind scale were developed mainly through ship-based data collection.[18] Gradually, meteorological interest shifted inland, requiring new tools and techniques. Gold's 1936 address thus began by noting advances in measuring instruments, particularly the Dines anemometer (designed in 1892 by William Henry Dines).[19] Pressure differences created by the wind blowing over horizontal and vertical tubes caused a float to rise and fall "in such a way that the rise of the float is proportional to the velocity of the wind."[20] A pen mechanism transformed the movement into a line drawn on graph paper. It marked an important step forward in measuring the wind more accurately, particularly compared to cup or vane anemometers, and, by 1914, twenty-five instruments were installed around Britain, ten on aerodromes.[21] Subsequent technical adjustments improved the data—for example, by noting wind direction. Real-world testing had led to further improvements by the time Gold gave his talk. A collaboration with the National Physical Laboratory in 1927 introduced a small shield to protect against gusts. Norwegian users suggested the addition of a small electric heating element around the tube to melt troublesome ice. And, in America, shallower cups were used to withstand exceptionally severe gales including a two hundred-mile-per-hour wind at Mount Washington, New Hampshire, on April 12, 1934.[22]

Gold was not satisfied: "Consider what we want an anemometer to record—nominally it is the wind. But the wind at a particular point depends not merely on the geographical situation of the place, but also on the obstacles in the immediate neighborhood and on the height of the point above the ground."[23] A record taken from the Lizard, mainland Britain's most southerly point, illustrated Gold's point. The anemometer went from "a very good exposure to a very bad one ... the cause was a row of coastguard cottages about 100 ft away ... the eddy from the cottages produced a much greater effect than had been anticipated; it caused the vane of the anemometer to swing right round, as the record shows, and the wind speed to oscillate."[24]

The wind moved differently due to the cottages. The anemometer was subsequently raised on a pole seventy-five feet above the ground to avoid the effects. Wind was situated: affected by, as well as affective of, its environment. Meteorologists called this interplay between wind and place the "topographical effect." Knowledge of the capacity for the built environment to influence the speed, flow, and strength of the wind encouraged meteorologists to look for "good exposure"—the "best" records were those uninfluenced by humans or architecture, and, thus, remote and sparsely populated places became increasingly valued as sites for wind measurement.

The quest to measure the wind accurately thus took meteorologists away from the RMS headquarters (and the first location of a Dines anemometer) in Kensington and aerodromes to the most exposed and isolated parts of the British Isles. Gold used wind data from the Orkney Islands, located sixteen kilometers north of the Scottish mainland, to illustrate a "good exposure" unencumbered by housing or complicated topography. The wind blew in westwards from the sea on the day of the anemogram (December 29, 1929) and was considered a "well defined wind"—there was "none of the disorganization shown by the Lizard records."[25] "Well defined" did not equate with smooth or steady, however. Data from Orkney, Tiree (the westernmost of the Inner Hebrides), Bell Rock (a lighthouse eleven miles offshore in the North Sea), and Shetland was compared to hypothesize the effect of the sea on the wind. Winds blowing in from the sea were more turbulent, affected not only by the long "fetch" (the length of water over which wind has blown) but also by the difference between (warmer) sea temperatures and (colder) air in these northern locations in winter. Here on the coastal edges of the nation, meteorologists considered the interrelationship between wind, land, and water.

Gold relied on data to construct his readings of the wind but did not hide the connection data forged with subjective, personal, interpretations. He presented some records "for their beauty."[26] Winds that produced rhythmic anemograms, and wind strength that emerged as wave patterns that rose and fell over hours, were valued because of their visual form, highlighting the fact that anemograms rendered the wind in visual data: the graphs drew winds in line form so that certain qualities became visually pleasing to those adept at reading them. The wind, a felt presence, became visible via data capture. Gold meditated on this reconstruction:

> The Dines instrument has given us a real picture of the wind: it makes a direct appeal to the imagination in more than one way. We see from its records the rhythm ... we see the wave-like blows and the relations of the long rolling clouds, and the dance of the gusts ... we can picture the storm: the fierce blasts come now from this way, now from that—we can see the trees swaying and the spray lashing—we can hear the whistling and the moaning and the roars. ... And we realise that the anemogram picture is not a complete representation of our experience. To man, the wind is not merely a velocity and a direction—it is a sound as well as a feeling.[27]

Gold resorted to sensory description due to the shortcomings of science in adequately capturing the full character of this force of nature. Introducing a record of the wind at Bell Rock on January 16, 1931, with a quote from *King Lear*—"Blow, winds, and crash your cheeks!

Rage! Blow! You cataracts and hurricanes, spout!"—Gold's reading of the wind was nuanced: "After a series of squalls, of more than 70 miles per hour, with each of which the west wind turns a little towards north only to drift back again to west, there is a real breakthrough between 3 and 4 am; the speed goes up from 30 to 40, from 40 to 50, and then, with a series of spurts, to 85 mph, as the last step in this change from west to north is effected, and the north wind triumphs."[28] This wind was a shape-shifter, transforming from a strong westerly into a wild northerly. Scientific data was used to create a vivid narrative in order to convey a sense of the wind's inherent kinetic thrust and changeable nature. Gold read the data as a story and, in his retelling, crafted a dramatic arc.

The address given to the members of the RMS in 1936 was a survey of scientific advances in wind measurement and a celebration of meteorology. But processes of data gathering had not simplified or clarified the wind—rather, the data had identified wind's complexities. The records showed winds to be expressive, responsive, and irregular, sometimes present in multiple forms. Wind interacted with the environment in ways that technology could not fully capture, and it evaded analysis by being gusty and unpredictable. In the 1940s, this was problematic for scientists, policy-makers, and engineers, who considered wind to be a potential energy source but who needed reliable data to inform the development of wind turbines. Subsequent experiments sought to further understand, and ultimately mitigate, the unpredictability of this potential energy source.

UNDERSTANDING WIND THROUGH PLACE

After the Second World War, large areas of rural Britain remained unconnected to public electricity networks, which had developed in an ad hoc manner in the early twentieth century through hundreds of companies and municipal undertakings, until industrial reform brought electricity gradually under full state control through a number of laws between 1926 and 1947.[29] But access to electricity remained geographically uneven. The Committee on Land Utilisation in Rural Areas estimated that, in 1939, about one-third of all rural dwellings were not yet electrified.[30] Planning for postwar recovery, the committee recommended that the "supply of electricity is an essential service which in due course should be available in the home of practically every citizen in town and country alike, at no higher price to the consumer in the country than in the town."[31] The postwar Labour government embarked upon a program of economic nationalization that included the electricity industry, with government oversight allowing to some extent the reform needed to expand its range. But economic recovery also necessitated import restrictions, which created material shortages and slowed grid expansion. In addition, coal shortages meant demand for electricity outstripped production. Most power plants in Britain burned coal, but coal mines had been steadily producing less: in 1938, 227 million tonnes of coal were produced; in 1946, coal output amounted to 189.25 million tonnes. The long-term decline was made acute by a very cold winter in 1946–47, when temperatures plummeted and domestic coal use rose in response.[32] The result was a fuel crisis with a highly visible, unpopular, and politically damaging end point: electricity blackouts. The British government began to seriously explore alternative sources of power.[33]

In Scotland, hydroelectric power was given state backing by the establishment of the North of Scotland Hydro-Electricity Board (NSHEB) by an Act of Parliament in 1943 to oversee energy provision for three-quarters of Scotland's landmass, and one-quarter of its population. The mountains and rivers of the Highlands suited hydroelectric development, but other underpowered areas lacked the necessary geography. Representatives of remote constituencies that remained partially or wholly unconnected to public electricity supply spoke in Parliament of the potential solution that wind-powered electricity could provide for the west coast, the Western Isles, Orkney, and Shetland—places without major water sources, coal reserves, substantial forests, or connection to the mainland national electricity grid.[34] Following peacetime nationalization of the electricity industry in 1947, the Department of Fuel and Power worked with the ERA to undertake research on the possibilities of wind-generated electricity, marking the beginning of state interest in the potential of wind power for public electricity supply.

British investigation into wind as a source of public electricity supply happened at a moment when progress elsewhere had paused. In 1933, the engineer V. N. Krasnovsky developed a one hundred-kilowatt turbine that fed into a grid in the Crimea for ten years. (It was dismantled during the Second World War.)[35] News of the Soviet achievement was followed by a report from the United States that Palmer Putnam had designed a grid-connected turbine built by the S. Morgan Smith Company in Vermont in 1941. The Smith-Putnam turbine ran until 1943, ultimately collapsing in 1945.[36] Both projects were the outputs of individual engineering "visionaries," and in the context of global conflict, neither the Soviet Union nor the United States pursued state-sponsored wind energy development after the demise of these projects.[37]

A commercial wind industry developed in North America, where expanses of sparsely populated land in Montana, North and South Dakota, Minnesota, and parts of Canada made grid construction an uneconomic proposition for electricity companies in the late nineteenth and early twentieth centuries. Entrepreneurs such as Charles

Brush developed small turbines that generated enough electricity to power individual farms and homes. Between 1927 and 1956, the Jacobs Wind Electric Company produced thousands of devices for rural farmsteads. But the scale remained one of individual provision, and when supply grids expanded following the Second World War, households generally took the opportunity to connect to the grid-supplied alternating current (AC). The market for self-generating wind machines disappeared, and attempts by Marcellus Jacobs and Percy Thomas to interest the US Congress in larger-scale projects in the early 1950s were unsuccessful.[38]

Denmark's pursuit of wind power also provided Britain with an example to follow. Early technological advances followed the pattern of individual inventiveness seen elsewhere: at the turn of the twentieth century, Poul la Cour developed turbines to provide farms, and a school, with power. Limited domestic resources—Denmark was largely deforested and had no coal reserves—encouraged innovative thinking. In 1902, la Cour founded the Dansk Vind Elektricitets Selskab, an electricity association, to assist in the development of decentralized electricity systems.[39] By 1918, 418 plants generating electricity were established through Denmark; many using diesel and gas, but approximately 120 using ten- to twenty-kilowatt turbines.[40] However, la Cour's models produced direct current, while Danish utility companies supplied AC. As public supply expanded, the market was captured by power plants producing AC using fossil fuels, and, by the Second World War, most Danish power plants ran on imported fossil fuels. With Soviet, American, and Danish progress paused, Britain explored wind as a potential component of the post-war national energy portfolio, albeit a small, experimental one, and began to develop wind as a source for public electricity supply.

To generate electricity from wind, state and industry needed information that went beyond the existing meteorological data. Precise information on where the wind blew strongest, most consistently, at what speeds, in what directions, and over what distances was needed to design and test resilient machines as well as to inform calculations of capital costs, projected profits, and the commercial viability of wind energy at scale. Some of this information could be drawn from existing records. But much of it needed to be gathered with the geographical consideration of electricity provision, and the technological consideration of wind turbine functionality, in mind. The ERA initiated a series of surveys, experiments, and expert assessments. The result was a series of reports establishing the suitability of coastal hills as sites for wind power generation and the first national wind survey.[41]

These reports shed light on how the state and its scientific institutions understood wind in the mid-twentieth century. They document a more precise range of considerations than the meteorologists identified. A focus on the energetic potential of wind shifted priorities away from general interest in its role in weather formation toward precise information on where it blew strongest, most consistently, and in relation to existing energy infrastructure. Politicians and scientists approached wind through a lens of technological development and commercial possibility. But its unpredictability and tendency to gust remained problematic.

Initially, the ERA looked to laboratories for answers, but wind for energy was best studied out in the field, where turbines eventually stood. The National Physical Laboratory (NPL) conducted experiments between 1934 and 1938 on the effects of vertical gusts due to their implications for airplane design and flight safety.[42] This science could be applied, in theory, to wind turbine design, where gusts disrupted the steady turning of turbine blades. In a confidential 1949 report for the ERA, the NPL aerodynamic expert R. A. Shaw noted that "the power which a wind driven generator will develop will depend on the average steady speed of the wind in which it is run; but the aerodynamic loads which it will have to withstand depend not so much on the steady wind speed as on the transient gusts to which it will be subjected."[43] Calculations of uplift and aerofoil sections were needed so that turbine blades were strong enough to resist gusts and remain attached and turning. Shaw applied information gathered about wind gusts in controlled experiments to the theoretical design requirements of wind turbine blades, which he viewed as "very similar for both wind driven generators and aeroplanes."[44] He noted that, where engineers had the capacity to design blades that could stall in too-gusty conditions, airplanes had to cope with dangerous loss of control mid-flight. Aeronautical engineers could not afford to miscalculate and, at the time of his writing, were developing onboard gust detectors. But planes were more susceptible to vertical gusts; Shaw saw that, for wind turbines, horizontal gusts would be the more critical concern.

While high-altitude aerodynamics could be simulated in wind tunnels, wind turbines were situated on the ground. This placement mattered to the movement of the wind. The controlled environments of the NPL's wind tunnels confirmed meteorologists' observations: wind behaved differently at low altitude when moving across land and sea. Gusts were measured at heights of 65, 150, and 450 feet above ground level. The maximum vertical gust velocities, expressed as a fraction of the steady wind speed, were 0.8, 0.6, and 0.35, the ratio diminishing with increasing height.[45] The closer the wind was to the ground surface, the gustier it was. These statistics established gustiness as a key issue for a wind industry whose turbines needed to be fixed to the ground to connect to the grid. It also reinforced Gold's observations that wind was responsive to the surface—be it earth, water, or architecture.

The ERA studied the relationship between land and wind more closely. Howard Rosenbrock authored a report on "the effect of hills on wind strength" in July 1949 that established that "the behaviour of the wind still remains largely unpredictable, and consequently the selection of sites tends to be slow and costly."[46] A precedent had been set by the Smith-Putnam generator, but "very little work had been done on the behaviour of wind in hilly country at the time," and the calculations made by the group "were the weakest aspect of their work, for although they succeeded in solving the considerable engineering problems associated with the windmill ... the wind at the site where it was installed gave only 30 percent of the power that was expected."[47] Such disparity between the estimated and actual power generation could not sustain a public supply or viable industry. Rosenbrock suggested that, by isolating the "variable factors" of a test site—roughness of ground, steepness of slope, shape of hills, and so on, measured geometrically—"it should be possible to judge their effect in any other proposed site."[48] The aim of scientists was to arrive at a universal formula that could be applied to every potential site. True site specificity was costly and time-consuming. Rosenbrock, as well as some of the other scientists employed by the ERA to assess the particular problems of wind power, wanted a way of establishing suitable landscapes for wind power from the laboratory. They theorized about wind movements using methodologies from aerodynamics, hydrodynamics, and studies of electrical current flow. Like Shaw, Rosenbrock referred to observations in aerodynamics about the flow of air over an airplane wing that "follows very closely the predictions of theory." Scientists wanted the wind to do likewise.

One key figure in the development of wind power in Britain, Edward Golding, deviated from this mindset. Golding advocated real-world testing for wind turbines. His research changed how wind was studied by showing that attention to landscape could explain, and even predict, how wind would behave. He was the technical secretary of the ERA's Wind Power Committee, oversaw the national wind survey, and with A. H. Stodhart, authored the first published ERA technical report. *The Selection and Characteristics of Wind-Power Sites* signaled a shift away from attempts to identify universal laws and formulae to determine wind power sites.[49] Instead, place-based research, site-specific field surveys, and engagement with local people became the means through which wind power sites were identified and tested. At the time of publication in 1952, the survey had lasted three years and covered Orkney, the Hebrides, the Channel Islands, Northern Ireland and northwest Ireland, as well as the western coastal districts of Great Britain. It then expanded to include several sites on the east coast and some in the Midlands and continued until the end of 1954 (figure 1).[50] For five years, the ERA surveyed the potential of the wind as a source of power generation, building a detailed national picture of

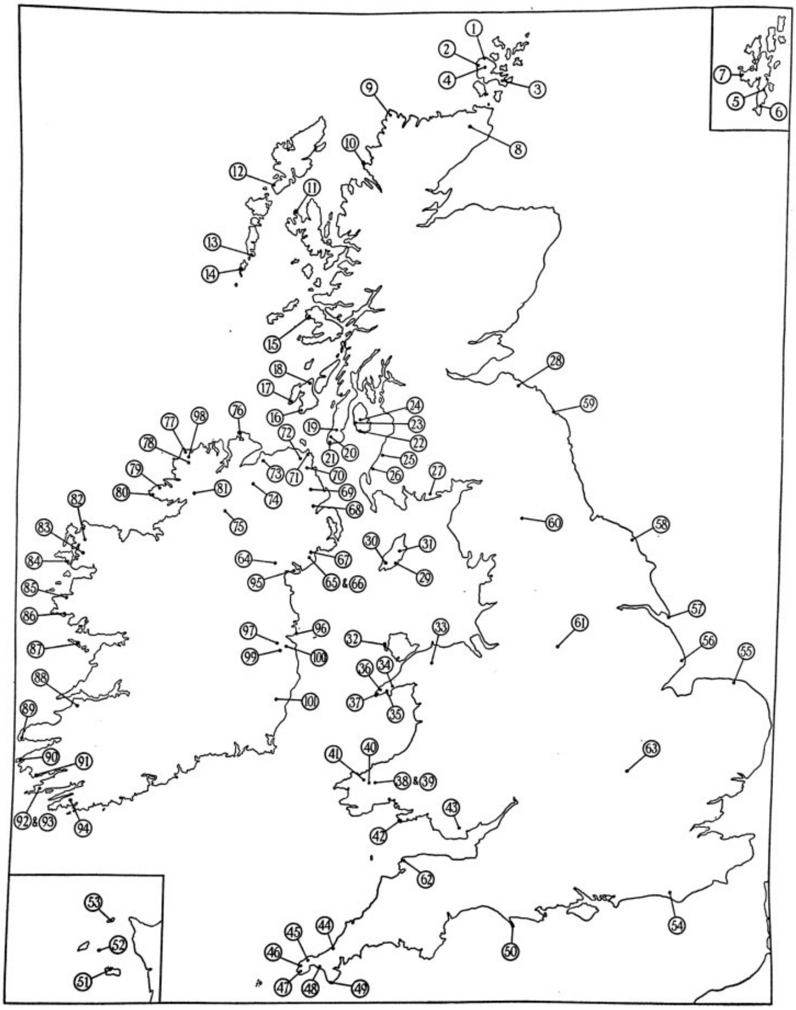

Figure 1. A map of sites surveyed for their wind conditions by the ERA, 1948–54. Credit: Originally published in J. R. Tagg, *Wind Data Related to the Generation of Electricity by Wind Power* (Leatherhead: ERA, 1957). Courtesy of the ERA Foundation, reprinted with permission.

wind activity. The research moved the generation of electricity by wind toward a reality that would operate in specific places and be encountered by people who lived and worked in those places.

The survey affirmed the highly changeable nature of the wind in Britain and the need for turbines to work with this variability. It presented methods for using the observed effects of landscape on the wind to determine suitable turbine sites. Survey sites were initially chosen from Meteorological Office wind data.[51] Isovent charts derived from anemometer records indicated areas with annual average wind speeds above fifteen miles per hour, to which was added the knowledge that hilly sites tended to be windier still. Golding and Stodhart noted that very windy hilly sites "are fortunately almost always devoid of trees presumably because the wind conditions are too severe for the growth of anything higher than low scrub or heather … in itself (this) acts as a rough guide to the probable suitability of the hill for wind power."[52] Two things emerge here: first, the survey process seems to have influenced the landscape perceptions of "good" and "bad." Golding and Stodhart saw the landscape through the wind, reading its qualities in relation to how and why the air moved as it did. Second, there is a clear departure in methodology from the 1949 reports. The emphasis here was on place, not theory, and the available data could only go so far to identify suitable test sites: "In almost every case at least one of the chosen hills has been discarded after inspecting on the site and has been replaced by an obviously better one which did not appear so attractive from the map."[53] Fieldwork was required.

Local help was sought to erect measuring equipment and keep an eye on it, with scientists specifying that "the equipment should be light and easily handled for transport over rough ground. Simplicity in design is an advantage since maintenance may have to be done by unskilled local observers."[54] In fact, the survey relied on the contributions of local people. It was "out of the question" for ERA staff to visit survey sites beyond the initial installation of equipment, so local observers were recruited for the weekly changing of the anemometer recorder charts.[55] Some of these volunteers were drawn from local electrical authorities, but the majority were simply people living nearby: farmers and their families, shepherds, postal workers, coast guards, utilities employees. These were people that the ERA found to "have occasion to climb the hills at intervals and have been most helpful" in data collection.[56] Place-based research methods were also people-based research methods.

To understand the wind, scientists needed to connect more closely with local environments and to consider landforms too. The reports identified key landscape features that indicated a viable wind regime for a power-generating turbine. Hills within one to two miles of the sea were the most promising; conical hills were as good as ridges in a prevailing wind; altitude itself was not a reliable criterion, with hills a few hundred feet high often as "good" as those that were well over one thousand feet. "Good" hills for wind power had bare summits. Any hills with trees or bushes growing near the top could be dismissed at once as unfavorable. Landscape features were the starting point for identifying potential wind sites. Map contour lines were as necessary as isovent diagrams to understand wind flows (figure 2).

The national wind survey was initiated by the NSHEB's interest in exploring wind power as a "auxiliary source" of energy for island networks, as laid out by the parliamentary debates that established it.[57] The survey constituted "the first step towards any reasonably accurate estimation of wind power potentialities in these islands," and the results were for engineers and policy-makers. The detail required was accordingly higher than a general survey due to the "expressed interest of the electricity generating authorities," and the chosen sites were largely coastal and remote.[58] In order to invest in wind, the NSHEB had to be convinced of its economic viability.[59] Consistency was key. Researchers were less concerned with the strongest single wind recorded (records that the RMS had kept for places with Dines anemometers since 1909) and more interested in where the strongest consistent wind regimes were to be found.[60] As the 1952 report noted, "a site in this country should have an annual average wind speed of between 20 and 25 mph if its use is to be potentially economic."[61] It established Orkney as the windiest site in the British Isles—and, therefore, for the ERA's and the NSHEB's purposes, the most productive—and the islands became the focus of the emergent wind industry in Britain in the 1950s.

Industry priorities also informed the research. More precise data on extreme wind conditions was necessary for "windmill designers" to build machines capable of withstanding weather, to justify investment, and to "ensure that wind power would be an economic proposition."[62] The "windmill designers" were John Brown and Company, Clydeside shipbuilders with extensive experience in manufacturing ship turbines and contracts with the NSHEB to produce turbines for gas power plants and hydroelectric dams. Wind turbine manufacture built on existing capabilities and positioned the company at the forefront of technical innovation.[63] But, working with wind, an uncompliant input into a technological system, required site-based prototype development. John Brown and Company employed a team of engineers and assistants in Orkney for the duration of the experiments.

The reports and national wind survey conducted by the ERA between 1948 and 1954 established the most detailed picture to date of how wind blew in and around Britain and Ireland. The work situated wind emphatically in place, connecting it to land formations, vegetation, and regions. It highlighted that people inhabiting windy sites possessed situated knowledge of how the wind operated and were best placed to record wind data. It also confirmed an observation made by Golding and Stodhart: "It is improbable that a high percentage of the energy available at any satisfactory site in the British Isles will be provided by winds from any one direction."[64] The wind in Britain was, by its nature, highly changeable, and the machines built to harness it would have to work with this changeability.

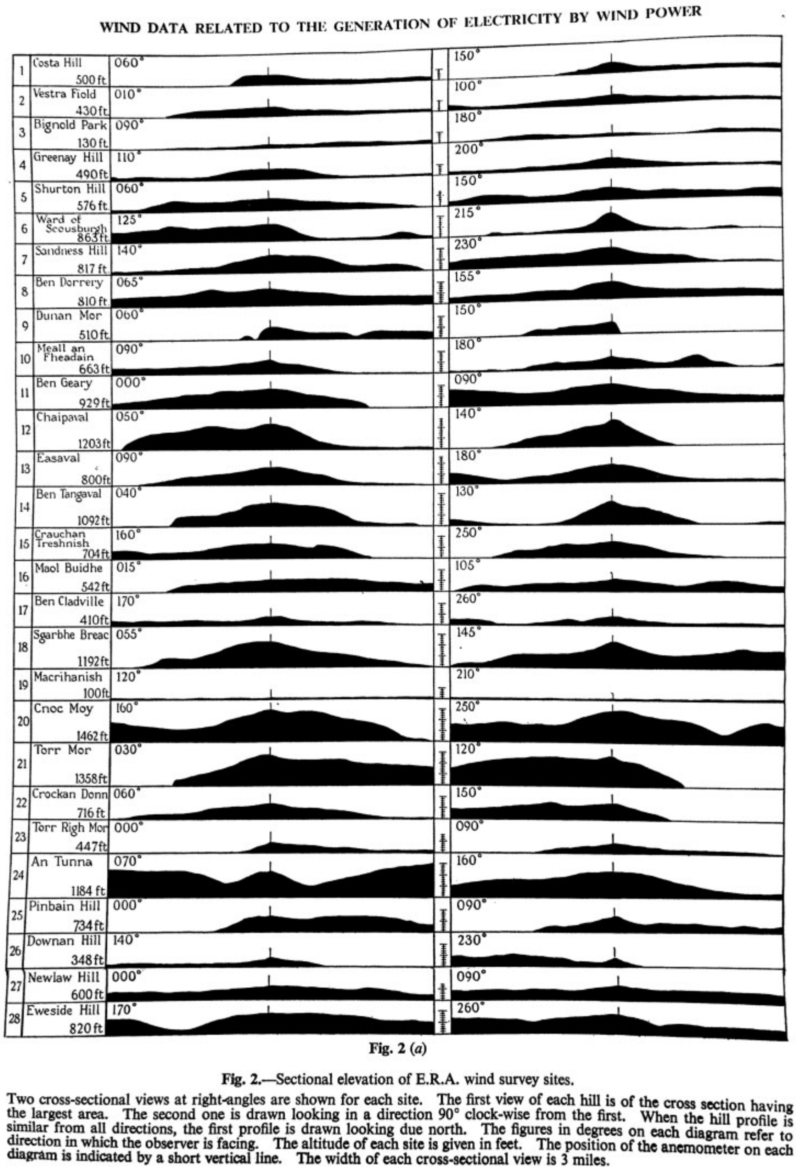

Figure 2. A sectional elevation of selected ERA wind survey sites. The width of each cross-sectional view is scaled to represent three miles. Credit: Originally published in in J. R. Tagg, *Wind Data Related to the Generation of Electricity by Wind Power* (Leatherhead: ERA, 1957). Courtesy of the ERA Foundation, reprinted with permission.

GENERATING ELECTRICITY AND IDENTITY

A closer look at Orkney shows how the development of wind power was shaped by, and fed into, notions of local particularity. A turbine capable of producing one hundred kilowatts per hour was raised on Costa Hill in 1951. The turbine had a nacelle gearbox and generator situated at the top of a seventy-eight-foot-high metal base structure and three thirty-foot blades made of metal and plywood able to rotate to face a changing wind direction.[65] The turbine tests lasted from 1951 to 1955 and made wind headline news. So did two hurricanes that hit the islands in successive years in 1952 and 1953. In response to the devastation wrought by these weather events, local people put the methods of measuring and analyzing wind strength and behavior developed in pursuit of energy production to different uses: to understanding and contextualizing island resilience in the face of extreme weather. Ways of thinking about the wind as measurable, energetic, and problematically unpredictable extended beyond industry discourse. Resilience to storm winds informed a sense of place and, with it, identity.

Local press coverage of the wind surveys in 1949 used national interest in wind to frame local particularity. A headline announced Costa Head as "Windiest Place in Britain," emphasizing the island's windy credentials. Other sites around the nation had been surveyed, "but in none of these were the results as satisfactory as at Costa."[66] News of planning permission for the turbines followed in 1950.[67] The reports rationalized the experiments along geographic, political, and technological lines: "Firstly, it is a very windy district; secondly, the North of Scotland Hydro-Electric Board at the commencement of the committee's work, expressed its willingness to operate a medium size wind-driven generator connected to its distribution network on the island; and thirdly, there are plenty of easily accessible hills, or apparently suitable slopes, lying quite close to the network."[68] The collation of technological need and geographic conditions echoed the remit and findings of the ERA's wind survey (figure 3). *The Orcadian* newspaper explicitly framed the wind in terms of its productive potential: "In northern and western Scotland, a considerable volume of power could be produced from the winds if economical and reliable machines were available." Wind was a technical challenge requiring economical and reliable solutions in order to release the power (and profit) bound up in the movement of air. This wind was productive and somewhat passive: a presence that reliable technology could harness.

The wind that blew in the early hours of January 15, 1952, was of a different character. Between 3 a.m. and 6 a.m., a hurricane hit Orkney with huge destructive force. A display of the "Merry Dancers" (the Northern Lights) was followed by an electrical storm until "the wind took charge."[69] An estimated 501 agricultural buildings were demolished or partly demolished, and 2,459 agricultural buildings unroofed or partly unroofed.[70] The animal cost was very high. The poultry industry brought in one million pounds sterling to the local economy annually; the storm wiped it out in three hours, with an estimated 76,541 birds lost.[71] *The Orkney Herald* reported "scores of poultry lying dead, some of them smashed up against posts and fences. One old sow was wandering down the road as if it was wondering how it had got there." Ten cattle, sixty-six sheep, twenty pigs, and one horse were killed by the storm: "It was almost incredible that (it) resulted in no casualties in the human population," probably because nearly everyone was in bed at the time it struck.[72]

Some reports relied on wartime metaphors to convey the nature of the storm. Fishermen observed that "the seas were not so bad. The force of the wind beat them flat, but the whole sky was filled with spray like smoke. It battered us like shrapnel." One Kirkwall man said: "Give me a blitz any time to that ... it was like hell let loose."[73] There was incredulity not just at the strength of the wind but also in the ways in which it behaved. One Kirkwall housewife described it as "freakish," having

> left a line of washing out and when the storm broke did not think it worthwhile going to take it in, thinking it would be

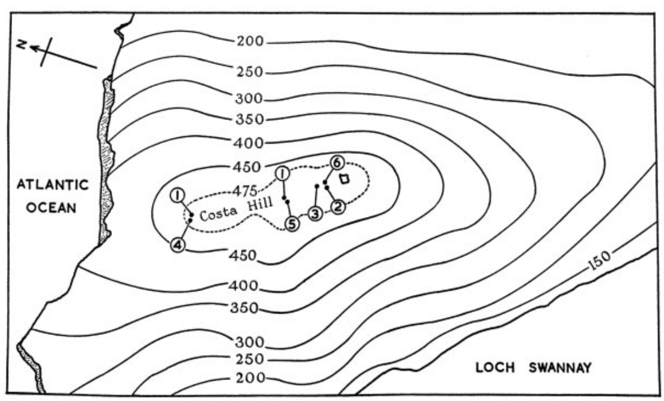

Fig. 18.—Contour plan of (1) Costa Hill, Orkney.
Scale: 1 in.=200 yards.

(1) and (2)—Original positions of cup counter anemometers mounted on 10 ft. poles.
(2) —Actual summit of Costa Hill at an altitude of 500 ft.
(3)* —Original position of the 66 ft. pole. This was later removed to make way for the 100 kW windmill.
(4) —Subsequent position of the 66 ft. pole.
(5)* —Position of the 120 ft. measuring mast.
(6)* —Position of a cup-contact anemometer mounted on a 10 ft. pole and used with the photographic recorder.
* Positions from which results were analysed.
The contour vertical interval is normally 50 ft. with the exception that the highest contour has been drawn at 475 ft.

Figure 3. A contour plan of the Costa Head turbine test site, Orkney. Credit: Originally published in J. R. Tagg, *Wind Data Related to the Generation of Electricity by Wind Power* (Leatherhead: ERA, 1957). Courtesy of the ERA Foundation, reprinted with permission.

> half across the county by the time she got to the garden. But the washing was still there next morning, all of it, though the two garden gates had been ripped from their hinges, heavy stones had been torn from the top of the wall.[74]

Such instances underscored the illogical, unpredictable nature of the storm wind. Angry, freakish, and in charge: this was a force of nature that defied attempts to render it productive.

The turbine survived the storm badly damaged, and repairs took months.[75] But the data generated by the anemometer attached to the machinery at Costa Head gave precision to the analysis of the wind's strength: the turbine registered gusts of 115 miles per hour. Nonetheless, the wind tested the limitations of the technology. The "needle on the anemometer … reached the maximum and then went off the recording chart."[76] This detail not only underscored the exceptionality of the wind but also spurred discussions of the precision and categorization of wind strength. *The Orcadian* posed the question: "when's a gale a gale?" The answer provided was that a gale began at fifty-five miles per hour, a storm at sixty-five, and a hurricane at seventy-two. Estimates of Orkney's hurricane blowing across the islands at probable speeds of 120 miles per hour rendered it remarkable: the strongest wind recorded in Britain. The information supplied by the turbine confirmed the storm to be off the scale; by comparing to categories of wind strength and records of winds elsewhere in Britain, Orkney's wind was made phenomenal.

The strong wind regime of the islands created a nuanced appreciation of wind's force, which fed constructs of local identity and particularity. Orcadian experiences of strong wind could not be compared to, say, "the leafy Lothians who are inclined to speak of a breeze of thirty miles an hour as an 'awful gale.'"[77] Nor was amazement at the storm's strength an overreaction: "In the North of Scotland and especially in the isles, and also in the fishing ports, we have cause to know the violences of nature. But very seldom, fortunately, is the wind so devastating as yesterday."[78] Orkney's long relationship with wind became key to understanding the particular power of the 1952 storm: "We (the islanders) have been rather proud of our capacity to endure and at times even to enjoy the gales that reach us in such numbers each winter," the same journalist writes. But thanks to the storm, "for the first time in the memory of living men the wind has become Orkney's bitterest enemy."[79]

A lifetime of memory remained an important way of gauging the weather on Orkney, but the presence of weather records augmented this embodied knowledge. The hurricane prompted some research by *The Orcadian* newspaper, which looked back into its archives for comparable storm reports. The reporter (named only as "E. M.") recounted descriptions of winds by historians, poets, and sea captains going back to 1693, when the historian Wallace wrote "The winds ... often blow very boysterouslie." By the nineteenth century, descriptions were more detailed, which, as the paper pointed out, not only reflected increased interest in weather in the period but also coincided with the collection of weather data. A Robinson cup anemometer was installed at Deerness in 1869, which recorded hourly average wind velocity. From 1869 to 1903, the anemometer showed that the wind only reached a speed over eighty-nine miles per hour on one occasion—in 1893, when a gale blew at ninety-six miles per hour. The weather station operator Magnus Spence said that, in that gale, the readings showed that "for half an hour [the wind] reached 100 [mph]," which was stronger than the average reading reflected (and indicative of the limits of anemometer technology).[80] That weather event was fixed in the public memory by the sinking of the Kirkwall schooner *Orcadian*, with the loss of the entire crew keenly felt by the community. The weather record underscored what public memory already knew, but it added an empirical base and reference point for subsequent storms—none as measurably bad until the 1952 hurricane. The exceptional strength of the 1952 winds was placed in a historical lineage of storms that allowed local people to go beyond living memory to access weather data. This knowledge framed Orkney winds as an environmental continuum, capable of moments of exceptional strength, but inherently part of Orkney life. Public appetite for information generated by the turbines placed wind in personal, local, and historical context. Wind was a component in the identities that sprang from these categories. As with the meteorologists and the engineers, island understandings of wind—its past, power, and potential—were situated in place.

The wind energy experiments conducted in Orkney in the 1950s emphasized the productive power of the wind and spurred narratives that hinted at future resource potential and economic prosperity.[81] The January 1952 hurricane, followed by another in January 1953, reasserted wind as a destructive force. It demonstrated the limits of meteorological equipment, by blowing stronger than anemometers could read. And it demonstrated the limits of wind energy technology by severely damaging the turbine blades. Concerns over the reliability and longevity of the technology were raised in *The Engineer*'s report on the experiments in 1955.[82] In addition to not being transportable and storable like oil and coal, wind was not inert. It did not behave itself. As a technological challenge, this factor had not deterred the NSHEB or John Brown and Company at the start of the decade. But by the mid-to-late 1950s, shipbuilding was facing increased international competition and narrowing profits; it was no longer advantageous to pursue experimental projects.[83]

The political context, too, had changed. In the 1950s, nuclear power became the centerpiece of national energy policy.[84] In the

Cold War context, it carried strategic significance and promised power at a scale capable of filling the coal shortfall. In practice, nuclear power would never match expectations, with plants proving so difficult and costly to build that the output was more expensive than coal. But with the Conservative government backing nuclear as the "alternative" energy source of the future (Calder Hall, the world's first civil nuclear power station, opened in 1956), wind energy no longer had the political momentum to drive further investment in technological development.

In the face of diminishing interest at home, wind energy advocates like Golding focused on facilitating international cooperation. From 1950 to 1952, Golding spearheaded a joint UK-Canada Wind Power Working Party, supported by the Organisation for European Economic Co-operation, with sixteen nations represented at four meetings.[85] Among the participants was Johannes Juul, a Danish engineer. Juul's work picked up where Britain's experiments left off. He secured a Danish government investment to test a two hundred-kilowatt turbine from 1957 to 1967. The technical adjustments made during these tests "would give Denmark the world lead in wind technology after the next energy crisis in 1973–4."[86] Golding continued to promote wind energy worldwide through articles in the United Nations Educational, Scientific and Cultural Organization's *Courier*, and his book *The Generation of Electricity by Wind Power* (1955), which became a handbook of sorts for the off-grid communities that maintained active interest in wind energy in 1960s and 1970s Britain.[87] Orkney's role in the development of wind turbines in Britain established a connection between the islands and wind energy that outlasted the loss of state interest in the late 1950s. When the British wind industry revived in the late 1980s, it turned again to Orkney to test new turbines. Today, the islands remain a hub for renewable energy technology testing and innovation. The connections between energy, place, and people, which the early turbine experiments reflected and informed, continue to develop.

CONCLUSION

Wind in mid-twentieth-century Britain was a multifaceted productive force. It generated electricity, scientific knowledge, and locally situated ideas of place, past, and identity, no less than gentle breezes and Atlantic gales. To develop wind technology, the British state, state-owned energy suppliers, and turbine manufacturers required information about how and where the wind blew most consistently and strongly. Meteorologists, physicists, and engineers developed new ways of "reading" the wind that used highly localized geographies and topographies, and the skills of local inhabitants, to accrue data and map the national wind regime. Conducted by national research bodies, the research emphasized that how wind behaved, how it was experienced, and how it could be harnessed was best understood at a local scale.

While energy policies and plans are typically crafted and implemented at scale, the history of the development of wind technology reminds us that not only is energy encountered at a more personal level—with turbines, pipelines, and mines materializing in lived landscapes; with sights, sounds, and smells creating affective energy environments—but that knowledge constructed through places and people is central to the siting and functioning of energy infrastructure. With wind and other renewable technologies generating increasing amounts of power (electrical, financial, and political), more work is needed on the historical concepts, processes, places, and people behind them, especially if societies are to extract themselves from the oil dependency of our fossil-fueled age.

As energy technologies have histories, so they leave legacies. When wind turbine experiments commenced again in Britain in the 1980s, Orkney resumed its place as the preferred test site for developing technology. A three megawatt turbine was installed on Burgar Hill in 1987 and ran until 2001, replaced by three more experimental machines. Two years later, the establishment of the European Marine Energy Centre took renewable energy experimentation into another rich Orcadian natural resource: the island's wave regime, an energetic space that is still putting technology to the test.

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Notes

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1 *House of Commons Debates* (May 6, 1943), vol. 389, col. 404–5. The debate addressed the 1943 Hydro-Electric Development (Scotland) Bill, which established the North of Scotland Hydro-Electric Board (NSHEB) as the energy provider for the far north. NSHEB developed hydropower to supply remote regions in the Highlands with electricity and explored wind as an alternative power source particularly for islands which lacked major watercourses.

2 See Deborah R. Coen, *Climate in Motion: Science, Empire and the Problem of Scale* (Chicago: University of Chicago Press, 2018), 205–36; Robert Marc Friedman, *Appropriating the Weather: Vilhelm Bjerknes and the Construction of a Modern Meteorology* (Ithaca: Cornell University Press, 1989). On the role of the British navy in developing meteorological science, see Simon Naylor, "Log Books and the Law of Storms: Maritime Meteorology and the British Admiralty in the Nineteenth Century," *Isis* 106 (2015): 771–97.

3 Greg Bankhoff, "Aeolian Empires: The Influence of Winds and Currents on European Maritime Expansion in the Days of Sail," *Environment and History* 23 (2017): 163–96.

4 As an archipelago, Orkney waited until 1982 to be connected to the mainland electricity grid via seabed cables. The turbine connected to the island grid.

5 On community uses of weather data and the capacity for weather to shape human engagement with place, see Lucy Veale, Georgina Endfield, and Simon Naylor, "Knowing Weather in Place: The Helm Wind of Cross Fell," *Journal of Historical Geography* 45 (2014): 26.

6 Ian Jared Miller and Paul Warde, "Energy Transitions as Environmental Events," *Environmental History* 24 (2019): 464–71; see also Dolly Jørgensen, Finn Arne Jørgensen, and Sara B. Pritchard, *New Natures: Joining Environmental History with Science and Technology Studies* (Pittsburgh: University of Pittsburgh Press, 2013).

7 J. R. McNeill and Peter Engelke, *The Great Acceleration: An Environmental History of the Anthropocene since 1945* (Cambridge: Belknap Press of Harvard University, 2014), 7. The idea of nature as an "envirotechnical" system originated in Richard White's *The Organic Machine: Remaking the Columbia River* (New York: Hill and Wang, 1995), and was developed by Sara B. Pritchard in *Confluence: The Nature of Technology and the Remaking of the Rhone* (Cambridge: Harvard University Press, 2011).

8 Christopher F. Jones, "The Materiality of Energy," *Canadian Journal of History / Annales canadiennes d'histoire* 53 (2018): 378–94.

9 Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880–1930* (Baltimore: Johns Hopkins University Press, 1983), 6; see also the eight-part typology of environment/technology interactions, which builds on Hughes's text, set out in Jon Agar and Jacob Ward, eds., *Histories of Technology, Environment and Modern Britain* (London: UCL Press, 2018), 1–21.

10 Richard Leslie Hills, *Power from the Wind: A History of Windmill Technology* (Cambridge: Cambridge University Press, 1994); Robert W. Righter, *Wind Energy in America: A History* (Norman: University of Oklahoma Press, 1996).

11 Mike Hulme, *Weathered: Cultures of Climate* (London: Sage Publications, 2016); Katherine Anderson, *Predicting the Weather: Victorians and the Science of Meteorology* (Chicago: University of Chicago Press, 2005); Vladimir Jankovic, *Reading the Skies: A Cultural History of English Weather 1650–1820* (Chicago: University of Chicago Press, 2005); Lucian Boia, *The Weather in the Imagination* (London: Reaktion, 2005).

12 Veale, Endfield, and Naylor, "Knowing Weather in Place," 26.

13 See, for example, Sarah Mittenfelhdt, "From Appropriate Technology to the Clean Energy Economy: Renewable Energy and Environmental Politics since the 1970s," *Journal of Environmental Studies and Sciences* 8 (2018): 212–19. David Nye outlines political reasons for the slow rate of transition away from fossil fuels in the United States, even in light of post-1970s climate awareness. David Nye, "The United States and Alternative Energies since 1980: Technological Fix or Regime Change?" *Theory, Culture and Society*, special issue, *Energy and Society* 31 (2014): 103–25.

14 Geoffrey Jones, *Profits and Sustainability: A History of Green Entrepreneurship* (Oxford: Oxford University Press), 41.

15 Colonel Ernest Gold established the first operational military meteorological service for the British army during the First World War, having observed the negative effects of "thermal winds" on British bombing missions. He was president of the Royal Meteorological Society (RMS) from 1934 to 1935. R. C. Sutcliffe and A. C. Best, "Ernest Gold. 24 July 1881 –30 January 1976," *Biographical Memoirs of Fellows of the Royal Society* 23 (1977): 114–31.

16 Ernest Gold, "Wind in Britain: The Dines Anemometer and Some Notable Records during the Last 40 Years," *Quarterly Journal of the Royal Meteorological Society* 62 (1936): 167–206, Bib no. 543594, National Meteorological Library and Office, Met Office, Exeter, UK.

17 For the significant contributions of lay weather knowledge to the development of formal weather science in nineteenth-century Britain, see Anderson, *Predicting the Weather*.

18 Naylor, "Log Books," 776–78.

19 In an address to the RMS in March 1882, attended by William Dines, then president J. K. Laughton had called for innovation and invention in the area of wind measurement.

20 Gold, "Wind in Britain," 183.

21 Ibid., 186.

22 Ibid., 178–79.

23 Ibid., 178, 186.

24 Ibid., 187–88.

25 Ibid., 188.

26 Ibid., 189.

27 Ibid., 193.

28 Ibid., 191.

29 See Leslie Hannah, *Electricity before Nationalisation: A Study of the Development of the Electricity Supply Industry in Britain to 1948* (Baltimore: Johns Hopkins University Press, 1979).

30 *Report of the Committee on Land Utilisation in Rural Areas*, Cmd 6379 (Richmond: Her Majesty's Stationery Office, 1942), 19, TNA CAB 117/140, The National Archives (TNA); see also Paul Brassley, Jeremy Burkhardt, and Karen Sayer, *Transforming the Countryside: The Electrification of Rural Britain* (Abingdon: Routledge, 2016).

31 *Report of the Committee on Land Utilisation in Rural Areas*, 16.

32 Labour Party, *Fuel Crisis: The Facts* (London: Labour Publications Department, March 1947).

33 See Marianna Dudley, "The Limits of Power: Wind Energy, Orkney and the Post-war British State," *Twentieth Century British History* 31 (September 2020): 316–39.

34 *House of Commons Debate* (February 24, 1943), vol. 387, cols. 230–31; *House of Commons Debate* (May 6, 1943), vol. 389, cols. 404–6.

35 Righter, *Wind Energy in America*, 127.

36 Ibid., 126–34.

37 Ibid., 127.

38 Ibid., 102, 127–45.

39 Bent Sørensen, *A History of Energy: Northern Europe from the Stone Age to the Present Day* (Abingdon: Earthscan, 2011), 388.

40 Ibid., 388.

41 The reports are held at the National Meteorological Library and Archive. The following reports are unpublished: R. A. Shaw, *Wind Driven Generators and Gusts*

(London: British Electrical and Allied Industries Research Association (ERA), 1949); H. H. Rosenbrock, *The Effect of Hills upon Wind Strength: A Note and a Suggested Method of Research* (London: ERA, 1949). The following reports are published: E. W. Golding and A. H. Stodhart, *The Selection and Characteristics of Wind-Power Sites*, ERA Technical Report C/T108 (Leatherhead: ERA, 1952); E. W. Golding and A. H. Stodhart, *The Use of Wind Power in Denmark*, ERA Technical Report C/T112 (Leatherhead: ERA, 1954); M. P. Wax, *An Experimental Study of Wind Structure (with Reference to the Design and Operation of Wind-Driven Generators)*, ERA Technical Report C/T114 (Leatherhead: ERA, 1956); J. R. Tagg, *Wind Data Related to the Generation of Electricity by Wind Power*, ERA Technical Report C/T115 (Leatherhead: ERA, 1957).

42 Shaw, *Wind Driven Generators*, 4.
43 Ibid., 1.
44 Ibid., 2.
45 Ibid., 1–2.
46 Rosenbrock, *Effect of Hills*, 3.
47 Ibid., 1.
48 Ibid., 3.
49 Golding and Stodhart, *Wind-Power Sites*.
50 Tagg, *Wind Data*, 9–10.
51 Ibid., 7.
52 Golding and Stodhart, *Wind-Power Sites*, 2–3.
53 Ibid., 9.
54 Ibid., 11.
55 Ibid., 13.
56 Ibid., 20.
57 Ibid., 10; "Costa: Windiest Place in Britain," *The Orcadian*, December 15, 1949.
58 Golding and Stodhart, *Wind-Power Sites*, 10.
59 Ibid., 10. For the economic history of post-1945 energy policy, see Martin Chick, *Electricity and Energy Policy in Britain, France and the United States since 1945* (Cheltenham: Edward Elgar, 2007).
60 The RMS's wind records in the nineteenth century were obtained by Robinson cup anemometers, which recorded mean wind speed. The Dines instruments were considered an "immense advance." Gold, "Wind in Britain," 169.
61 . Golding and Stodhart, *Wind-Power Sites*
62 Tagg, *Wind Data*, 7.
63 John Brown and Company, "Letter to the Editor: Gas Turbines," *The Economist* 157, no. 5530 (August 20, 1949); John Brown and Company Annual General Meeting Report 1951, *The Economist* 16, no. 5637 (September 8, 1951). There is more research needed on the role of shipbuilding and other heavy industry in the development of renewable energy. Archive closures due to the coronavirus pandemic limited my own research into this area while revising this article; I hope other scholars can take this forward.
64 Golding and Stodhart, *Wind-Power Sites*, 26.
65 "Power Windmill Is First in Britain," *The Orcadian*, January 26, 1950; Correspondence between T. Mensforth for John Brown and Co. and North of Scotland Hydro-Electric Board, October 9, 1952, UCS 1/104/48, University of Glasgow Archive.
66 "Costa: Windiest Place in Britain," *The Orcadian*, December 15, 1949.
67 "Power 'Windmill' Is First"; "Wind Power," *Orkney Herald*, January 31, 1950.
68 "Costa: Windiest Place."
69 "120 Mph Hurricane Hits Orkney," *The Orcadian*, January 17, 1952.

70 "Hurricane Damage Estimate Nears £500,000," *Orkney Herald*, January 29, 1952.
71 Ibid.
72 "Wreckage-strewn Countryside," *Orkney Herald*, January 22, 1952.
73 Ibid.
74 Ibid.
75 Correspondence between Mensforth and North of Scotland Hydro-Electric Board, October 9, 1952.
76 "When's a Gale a Gale?" *The Orcadian*, January 24, 1952.
77 "Orkney and the Wind," *The Orcadian*, January 24, 1952.
78 "The Angry Winds" (syndicated article), *Orkney Herald*, January 22, 1952.
79 "Orkney and the Wind."
80 Ibid.
81 Similar themes emerged when the world's first wave energy technology test site was established on Orkney in 2003. First Minister Alex Salmond described the islands as the "Saudi Arabia of marine energy." "Project Aims to Harness Sea Power," *BBC News*, September 28, 2008, http://news.bbc.co.uk/1/hi/scotland/highlands_and_islands/7638242.stm.
82 John Ventners, "The Orkney Windmill and Wind Power in Scotland," *The Engineer*, January 27, 1950, 106–8.
83 Hugh Murphy, "'No Longer Competitive with Continental Shipbuilders': British Shipbuilding and International Competition, 1930–1960," *International Journal of Maritime History* 25 (2013): 35–60.
84 Hannah, *Engineers, Managers and Politicians*, 229.
85 Organisation for European Economic Co-operation, *Technical Papers Presented to the Wind Power Working Party* (London: Her Majesty's Stationery Office), Bib. no. 243495, National Meteorological Library and Archive.
86 Sørensen, *History of Energy*, 396.
87 E. W. Golding, *The Generation of Electricity by Wind Power* (New York: E. & F. N. Spon, 1955).